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(54) Title: CDPD/FM IP COMMUNICATION SYSTEM

(57) Abstract: The invention allows the delivery of high bandwidth information to mobile communication devices. A communication device transmits in one communication mode, for example CDPD, and receives in another communication mode, for example by FM sub-carrier. The communication system uses FM broadcast facilities to deliver high bandwidth information in response to requests transmitted by the device to a CDPD network in CDPD mode. A server coordinates FM channel set up and FM channel assignment independently of the CDPD device transmission channel asignment. FM channel set up is conducted entirely in CDPD mode. An FM signal strength mapping database can be derived from quality of service information generated during communication sessions.

TITLE OF THE INVENTION

CDPD/FM IP COMMUNICATION SYSTEM

TECHNICAL FIELD OF THE INVENTION

This invention relates to wireless IP communications. In particular this invention relates to a communication system and protocol for a wide area wireless network.

BACKGROUND OF THE INVENTION

The majority of wireless networks use licensed frequencies and two-way communications over a single broadcast technology. In addition, even with unlicensed RF technologies, the network structure and compression techniques are usually proprietary in nature and, because unlicensed wireless technology involves low power RF transmission, their applications are limited in range and tend to be applications that are best suited to underdeveloped areas without access to fiber optics or high capacity wire-line systems to provide bandwidth.

The desirability of creating a low cost wide area wireless network which sidesteps POTS and which avoids licensed technologies as much as possible and which also provides for a range of coverage which is not limited by low power transmission capabilities is addressed in the invention.

Some prior art approaches to wireless communications have involved conversions between protocols or the use of multiple communication media.

U.S. Patent No. 5,953,322 to Kimball describes a cellular Internet telephone system in which the cellular telephone generates a set of digital data representing a voice signal and encapsulates the data into a payload comprising either a data packet or an IP packet according to whether the communication is with a public switched telephone device or with an Internet telephony device. A base station receives the payload and if it contains an IP packet, the IP packet is extracted and is dispatched over the communication network. If it contains only the digital data, it is dispatched via a public switched telephone network.

U.S. Patent No. 6,006,105 to Rostoker et al. recognized the problem of incompatibility of cellular communication protocols and described a cellular telephone having means to convert from one protocol to another.

U.S. Patent No. 6,021,433 discloses a communication system wherein information update notifications are broadcast on a nationwide basis to wireless receiving devices associated with computer terminals. The notifications include URLs associated with desired information that the computer devices can then access through a communication network.

It is an object of the present invention to provide a large coverage ubiquitous communications network, that will avoid expensive licensed frequencies, infrastructure costs and proprietary technologies. The network will utilize spare commercial radio capacity and make use of existing transmission opportunities to provide a low cost alternative for existing static and mobile wireless communication devices using Internet Protocols (*IP*).

SUMMARY OF THE INVENTION

The present invention provides for a CDPD (*Cellular Digital Packet Data*) wireless network structure in which the client possesses a transmission device, for example a cell phone, handheld device, lap top or any other hybrid convergence device that has the capacity to broadcast IP information over a cellular CDPD network, and has the ability to dynamically receive FM sub-carrier TCP/IP digital information.

All present FM sub-carrier systems use a one way transmission protocol. The data is transmitted in a certain pre-defined simplex format to ensure it is received at the wireless device with no errors. This invention utilizes the reverse channel of a CDPD network to create a two-way protocol called Sub-Carrier Wide Area Protocol *(SC-WAP)*. With SC-WAP the two way wireless link becomes very flexible in the context of an IP packet switched network. The system will be able to dynamically assign and utilize spare radio capacity on any broadcast network by using limited transmissions on the CDPD network. In the preferred embodiment of the invention the broadcast transmission link is an FM sub-carrier, but the WAP Gateway system and protocols may be applied to any broadcast technologies.

In one aspect the invention is a communication system comprising a plurality of two way mobile communication devices capable of transmitting and receiving information in CDPD mode and having an FM radio broadcast receiver, a CDPD network for transmitting and receiving information to and from the device in CDPD mode, and a broadcast facility associated with the communication system for FM radio broadcast transmission to at least one of the devices. More particularly the FM broadcast is by FM sub-carrier.

The foregoing system allows the devices to transmit Internet access requests in CDPD mode but to receive broadband information in response to such requests by FM broadcast.

In another aspect of the invention, each communication session in the system involves a channel set up segment for establishing a radio transmission path to said device, and an information exchange segment. The channel set up segment is conducted in CDPD mode while the information exchange segment (i.e. accessing or communicating information) operates using FM sub-carrier as the return path to the device. The set up segment may occur repeatedly during a communication session.

In another aspect of the invention, a server coordinates the communication paths in the system and the set-up segment comprises a first data packet dispatched from the device and addressed to the server, the first data packet including the IP address of the device, and a reply data packet is dispatched from the server to the Internet and gets routed to the device through the CDPD network. The reply data packets identify a radio frequency at which the device is to receive information during the information exchange segment.

In another aspect of the invention, the location of the device is determined by comparing the receipt of said CDPD mode transmission at a plurality of cellular base stations. This assists the server in allocating a transmission facility and frequency for the return data path to the device. Preferably the location is determined using a time difference of arrival assessment and hyperbolic trilateration. The invention may also use signal quality associated with given device locations to assign broadcast facilities and frequencies.

In another aspect of the invention, the device transmits in CDPD mode a data packet including the IP address of the server and a URL to which the device desires access. The server replies by specifying to the device an FM frequency to which to tune and retrieves from the site identified by the URL the desired information and forwards it to the broadcast facility for transmission to the device.

In another aspect of the invention, a server coordinates communication between a mobile communication device and an IP address on a wide area communication network, said communication involving at least two modes of communication, a first of said modes comprising transmission by a broadcast facility of information to said device by FM radio, and a second of said modes being different from said first mode. The server has access to a database of broadcast facilities available for transmitting information at said server's request and the server selects a facility from said database for the transmission, based on the location of the device.

In another aspect of the invention, the server transmits encryption key information for facilitating decryption of an FM sub-carrier signal broadcast to said device.

In another aspect of the invention, the server confirms that said device is tuned to a designated FM sub-carrier frequency by receiving from the device a data status packet indicating that said device has tuned to a FM stereo pilot signal.

The server may also dispatch a test packet to the Internet being addressed for broadcast from said broadcast facility to said device, and the server detects a return packet from said device comprising said test packet.

The server also acts to ensure ongoing connectivity and quality of service by monitoring the quality of the FM radio signal received by said device. The server receives from said device information via a CDPD link regarding bit error rates in relation to said FM radio transmission to said device.

In another aspect of the invention, the server stores information regarding the quality of radio signal received by said device and dynamically correlates it with the location from time to time of said device to produce a quality of signal service database.

The quality of signal service database may be used to anticipate loss of acceptable signal quality as the device moves to a different location, enabling the server to allocate a different broadcast facility or frequency accordingly.

In another aspect of the invention, the server monitors communication session involving said device and said broadcast facility to detect inactivity or loss of connection.

In another aspect, the server maintains a channel assignment table identifying FM radio frequencies being used for communication, and wherein said server monitors said communication sessions and clears said channel assignment allocation for a communication session when the period of inactivity for said session exceeds a predetermined limit. A level of priority can be allocated to individual communication sessions involving said devices.

In another aspect of the invention, a mobile communication device is provided that is capable of transmitting in TCP/IP mode over a CDPD

network, and of receiving TCP/IP information via an FM radio receiver tuned to an FM sub-carrier channel. The device communicates with a host server for the purpose of determining a radio frequency to which said device should tune to receive said FM sub-carrier transmission.

In another aspect of the invention, the device functions in a full duplex CDPD mode during service request and FM channel assignment and in simplex FM sub-carrier mode (receive only) for data delivery. The device transmits FM sub-carrier channel status information in CDPD mode and contains bit error monitoring circuitry for detecting bit error rates when receiving FM radio transmissions and it monitors incoming FM data packets for acceptable bit error rates. The device also has signal monitoring and verification circuitry and detects and monitors the presence of an FM stereo pilot signal, for verifying FM channel allocation and for dispatching to a communication server confirmation that the device has received said FM stereo pilot signal.

In yet another aspect of the invention, a communication system is provided, comprising a plurality of two way communication devices, said devices being capable of transmitting information in a first communications mode and of receiving information in a second communications mode and a transmission facility broadcasting to at least one of said two way communication devices in said second communications mode.

In another aspect of the invention, the communication system comprises a server for receiving and forwarding information requests originating with said communication devices and communicated to said server via a wide area communication network, and for controlling the delivery of information responsive to said requests to at least one of said devices via said transmission facility.

In a further aspect of the invention, a communication system is provided that assigns return path channels to a mobile device independently of the assignment of the outgoing path channel from the device.

Other aspects of the invention will be appreciated by reference to the detailed description thereof and to the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the invention will be described by reference to the drawings thereof in which:

Figure 1A, 1B, 1C and 1D collectively illustrate the complete Sub Carrier Wide Area Protocol Network according to the preferred embodiment of the invention;

Figure 2 is a state diagram illustrating the Sub Carrier Wide Area Protocol for channel Set-up, Verification and Initial Response according to the preferred embodiment; and,

Figure 3 is a state diagram illustrating the Sub Carrier Wide Area Protocol for Ongoing Data Transfer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the invention enables a user to browse or transact over the Internet by means of a portable or stationary communication device. A user wishing to obtain information from a web site sends a CDPD message to a cellular base station in a CDPD network. The cellular network sends the message through the Internet to the host server, known as the WAP Gateway. The host server re-routes the request to the desired URL and retrieves the information requested by the user. The WAP Gateway then re-routes the information through the Internet to an FM broadcaster, which then broadcasts the information on a sub-carrier for reception by the user's communication device.

The user uses a mobile terminal or communication device 1, which contains a CDPD modem to transmit its public static network entity identifier (NEI) IP address along with a known host server IP address. It also transmits the IP address of the destination URL 10 with which the user wishes to establish communication. This information is transmitted as IP packets which are received at the CDPD network's cellular base stations (BTS).

After the IP packets arrive at the BTS, the packets are forwarded through a network service access point (NSAP) 3 to the Internet 4. The Internet routes the packets to the host server 5 by reference to the host server's IP address. Upon receipt of the packets (transmitted from the device) at the cellular base station the location of the transmitting mobile device 1 is derived using time distance of arrival (TDOA) analysis. Since the transmission of the IP packets is received at different times at different BTS's a TDOA processor 6 can calculate the device's location using hyperbolic trilateration. The location is derived using the known GPS coordinates of the BTS's and the device's transmitted signal time times of receipt at respective BTS's. The TDOA processor 6 will process the information and forward the device coordinates, along with the mobile's IP address, to the host server whose IP address is pre-programmed in the mobile device 1. This host server functions as a wide area protocol gateway and will be referred to as the WAP Gateway.

The WAP Gateway 5 now has two pieces of information, namely the transmitting device's public static IP address and the location information 14 provided by the TDOA processor 6. A database 7 associated with the WAP Gateway contains a complete list of all participating FM stations with Internet connections as well as their gateway IP addresses, their

geographical coordinates and their sub-carrier transmission frequencies. The WAP Gateway 5 will interrogate its database 7 and search the FM station coordinate information for the closest FM station to the mobile device 1. That FM station 9 will be the final destination to which packets will be routed for FM transmission back to the mobile communications device 1.

The WAP Gateway sends to the mobile device 1 information identifying the FM station's sub-carrier frequency to be used for transmission to the device 1. This is done via the same CDPD primary link 8 used to receive the initial service request from the device 1. The device uses the FM sub-carrier frequency to information to tune its built-in FM receiver. This will be the frequency on which the mobile device will receive its IP packets (referred to as the "secondary link"). After the sub-carrier transmit frequency information is sent via the primary link 8 to the mobile device 1, an encryption key packet is also sent by the WAP Gateway 5 via the primary link 8. The encryption key packet instructs the mobile device how to decrypt the off-air signal that will be received when packets arrive to the mobile device's FM receiver via the secondary link 9. The mobile device 1 acknowledges that it has tuned to the desired FM frequency by detecting the broadcaster's standard FM 19Khz stereo pilot and sending a pilot status packet back to the WAP Gateway 5 via the primary link 8. This pilot status packet confirms the detection of a 19 kHz FM stereo pilot. As all stereo FM stations utilize a 19 KHz pilot, this informs the WAP Gateway only that the mobile has tuned to an FM station.

While the likelihood is great that the device will have tuned to the stipulated FM station, the WAP Gateway 5 will conduct a channel verification by pinging the mobile device 1 through the secondary link 9. The ping packet will be routed to the transmission facility __ via the secondary link ___. The ping packet acknowledgement from the mobile device is

routed through the primary link 8 back to the WAP Gateway 5, thus verifying that the mobile device 1 is tuned to the assigned sub-carrier frequency. In order to ping for verification, the WAP Gateway 5 performs a network address translation (NAT) on the IP address of the mobile device 1 to route the ping packet to the FM transmitter and subsequently to the IP address of the mobile device 1. The NAT uses protocols familiar to those skilled in the art.

The foregoing steps relating to service request, channel assignment and confirmation comprise a channel set up segment of a communication session.

A channel status packet (*CSP*) is used to send the mobile device's 1 current status of the received FM sub-carrier's 19 kHz pilot as well as the quality of the received FM signal (the bit error rate BER). Any changes exceeding the preset threshold limit value in pilot signal and or bit error rate at the mobile will trigger the transmission of another CSP to the WAP Gateway to indicate a degradation of signal in the FM sub carrier secondary channel link. The CSP containing the information regarding pilot status level and BER will update a channel assignment table at the WAP Gateway (5). This table contains all the specific communication session information regarding the status of the mobile user's connectivity. The CSP will refresh this table information when the pilot signal status changes and/or when the bit error rate exceeds predefined levels.

If the pilot signal is unacceptable, the channel assignment table will revert the mobile to the CDPD primary link 8, before reassigning it again to another FM transmission facility and frequency. Similarly, if the maximum bit error rate is exceeded, the channel assignment table will revert the mobile to the CDPD primary link 8 before reassigning to another FM facility

and frequency. The CDPD primary link 8 will be activated and become the fallback channel when any sub-carrier channel signal is lost, degraded or reassigned until a reliable FM secondary link is established. When any channel reassignment takes place, transmission loop connectivity to the mobile device 1 is verified with a ping packet before the channel is made active in the channel assignment table.

After reestablishing a new active IP channel routing connection, the channel assignment table will be updated to include any new CSP values and will change dynamically throughout the mobile session to ensure channel continuity. The channel assignment table is a database that contains the mobile IP address, the Network Service Access Point (NSAP) IP address, the last known FM sub carrier Gateway IP address, the TDOA information regarding the longitude and latitude of the mobile, the last pilot signal status, the last bit error rate status, the last ping packet status, the last successfully active routed channel and the pre-defined session timeout limit (STL). The STL is a timer in the WAP which tracks inactivity in data transmission from the mobile. If the STL value is exceeded, the WAP Gateway 5 will cancel the FM sub carrier routing connection and default the mobile back to the primary CDPD link 8. The coordinates of the mobile will always be cross-referenced to the geographic location table of FM carriers to ensure that the signal to the mobile is always sent through the closest available FM station 11.

A channel allocation database also contains information regarding the assigned priority of the mobile user. The invention will use three types of channel loading control to achieve maximum allocation efficiency and to allow for hierarchical allocation of service. The invention will use Demand Access Multiple Assignment (DAMA), Partial Demand Access Multiple Assignment (PDAMA) and Pre-assigned Access Multiple Assignment

(PAMA) software to control bandwidth saturation and channel availability of the return FM (secondary) path. This load control software will be employed in the WAP Gateway 5. The load control software will keep track of the number of concurrent IP connections dynamically and ensure that they do not exceed the maximum pre-assigned value for each FM sub-carrier channel 16. The load control software will distribute the user traffic according to specific parameters: TDOA information; the mobile's pre-assigned priority; the status of the secondary channel; information regarding user membership in preferential groups which have been pre-assigned channel rights; time stamping to ensure that the channel assignments takes place only after all the necessary verification procedures have occurred and that those procedures have occurred in a timely sequence, and verification that limits of maximum TCP/IP assignments per channel have not been exceeded.

Having established the location of the closest FM sub-carrier 9 and tuning the mobile to that frequency, the WAP Gateway 5 will now perform another NAT. The NAT is performed on the mobile's IP address. The NAT will assign the WAP Gateway address 5 as the new return public address to be sent over the Internet 16 and will route the request to the requested URL or other destination via the primary link 8. Once the requested information is returned and routed back to the WAP Gateway from the destination server it must now be routed to the IP address of the ISP of the FM station 11. The WAP Gateway will now perform another NAT. This new public address will contain the IP address of the mobile device within its address. This internal address is the static address of the mobile device itself. The external routable destination address will be the address of the closest FM station 11. This address information will include the WAP Gateway IP address as the sender's address, and the FM sub-carrier's router's or gateway 11 IP address as the recipient's address but will include within it

the mobile device's IP address. When the IP packets arrive at the FM station gateway 11 over the public IP network 15, the router at the FM gateway will strip away the WAP Gateway IP address to reveal the mobile device's IP address. It will then forward the requested URL information which the user had originally requested to the FM sub-carrier modulator 16 to be broadcast to the IP address of the mobile device 1 using the preset FM sub-carrier frequency to which it had previously tuned.

The resulting IP routing now produces a full duplex secured wireless IP connection between the mobile user 1 and the destination URL 10. The advantages of this network are that it is asymmetric in nature. CDPD is limited to 19.2 kilobits per Sec (Kbps) in the forward RF link, and in the reverse (secondary) link the receive bandwidth can be a high as 2.4 Megabits per second (Mbps). The network can also support multiple TCP/IP sessions so that more than one user can be on both the CDPD primary link 8 as well as the same FM sub-carrier secondary link. In the forward portion of the primary CDPD link 8, IP data transmissions will be kept to a minimum as the user will typically only send the keyboard information and mouse clicks that are characteristic of use of Internet applications. The mobile device 1 periodically sends a channel status packet (CSP) over the CDPD primary link 8 back to the WAP Gateway 5. The interval of sending the CSP will be determined by the bit error rate and pilot status of the FM Sub-carrier signal. The CSP indicates the condition of the received FM sub-carrier signal and the status of the secondary link. The WAP Gateway uses the CSP information for channel verification and routing (8 or 9). Also the WAP Gateway will verify that the mobile user is online by sending a ping packet over the active channel periodically following specifications in a global setting table residing at the WAP Gateway database 7. This user online verification ping packet is sent periodically and continuously throughout the mobile user's online session until such time as

either the global session timeout value is exceeded or new activity occurs on the mobile to reset the session timeout timer running in the WAP Gateway.

Channel Loading Control software in the WAP Gateway would have thresholds set for maximum number of IP assignments per FM sub-carrier, as well as information concerning the location of the next closest FM sub-carrier to which the mobile would be reassigned if the maximum number of IP assignments for the nearest FM sub-carrier had been exceeded according to coordinate matching information. A subscriber would not be denied service if no FM sub-carrier channels were available because the WAP Gateway would assign a CDPD connection as the return route until such time as FM sub carrier channels became available.

A priority field in the channel assignment table in the WAP Gateway would determine the priority of the user and re-assign the IP to a different sub-carrier if the channel needed to be allocated to a higher priority user. The WAP Gateway server will receive a CSP back from the CDPD network primary link 8 to ensure handoff of reallocated users was established successfully. Because the device coordinates information is being kept up to date, it can be cross-correlated with CSP information to build a signal strength map database for all FM sub-carriers. It does this dynamically, based upon the activity of many users over time. This map indicates degraded signal strengths in different areas and it is used to anticipate a mobile user approaching an area of degraded signal so that a hand-off can occur before the signal is compromised. Similarly the signal strength map database can also be used when FM sub carriers are initially allocated. Instead of allocating the closest or strongest signal FM sub carrier (which would normally be the case) the database would enable the WAP Gateway to avoid allocating FM sub-carriers to mobile users in area where the signal

was compromised. This means that the WAP Gateway knows whether there are 'blind spots' within an FM sub carrier's range and reallocate mobile FM receiver frequencies accordingly.

The CSP encoder at the mobile incorporates hysteresis in both the pilot level signal and BER alarm threshold values. This hysteresis prevents channel toggling and omits transmission of unnecessary CSP packets over the reverse CDPD link back to the WAP Gateway, thus preventing oscillations in channel switching. Once the threshold pilot level or BER value has been exceeded at the mobile, a CSP is triggered and sent to update the CA table in the WAP Gateway. It will not send another CSP unless the pilot level value or BER value restores to a lower threshold point than the original upper limit threshold point. This creates a dead band of values where no updated CSPs are forwarded to the WAP Gateway (hysteresis). In conjunction with this hysteresis at the mobile's CSP encoder the WAP Gateway will contain in the global settings table a minimum switch time between routing the primary and secondary channels. Any CSP request arriving at intervals lower than the minimum switch time will not be acted upon.

In a fixed wireless application the WAP Gateway would apply a PAMA assignment. The static IP address of the fixed terminal device would be cross-referenced from a table to be assigned to a permanent FM Sub-carrier matching the TDOA information. PDAMA can also be used on fixed wireless applications where the assignments are made to a pre-defined group of sub-carrier channels on a rotational basis. In this way any one FM sub-carrier failure would not result in a CDPD return path. The PDAMA assignments would simply select the longest idle FM channel from the PDAMA pool of dedicated sub carrier frequencies. The PDAMA allows for provision of a guaranteed level of service by dedicating a specific number of FM sub

carrier channels to a specific number of fixed users. A system table would be made to create groups of PDAMA channel blocks and assign the static IP addresses of the fixed users associated with them.

In a mobile wireless application the WAP Gateway would apply a DAMA assignment. The static IP address of the mobile device would be cross-referenced by the updated TDOA information stored in the WAP Gateway which would assign an FM sub-carrier frequency selected from a predefined field of DAMA FM sub-carriers. If a DAMA channel reached maximum TCP/IP usage according to the threshold table for that particular station the WAP Gateway would select the next available DAMA Station based on the device coordinates. In this mode of operation the mobile can be handed off from sub-carrier to sub-carrier (with an Intermediate CDPD connection) by updates of the device coordinates. Handoffs would not be very frequent or not at all as the broadcast signal is a wide area signal. The DAMA software would be aware of both the geographic location and the number of channel TCP/IP users that were in use for each FM sub-carrier. It must be noted that the forward CDPD channel in a mobile environment is handed off by the cellular network and has no relationship to the reverse channel switching. Handoffs in the forward channel would be more likely because the cellular networks are based on much smaller RF powers and areas of coverage.

The WAP Gateway has large caching capabilities. The caching of every concurrent IP connection between the WAP Gateway and the destination server would speed up the system because duplicated destination requests would not need to be transmitted as the relevant destination information would already reside in the WAP Gateway. WAP Gateway caching would save one set of NATs every time the WAP Gateway

had a cache hit. Also cross caching would save time when pages from one IP connection were accessed for similar information by another IP connection request. Cache clearing would be setup in a global table in the WAP Gateway to occur when a predefined amount of time had passed or when the user session ended. Selective and adaptive caching would also occur to save time by retaining information concerning processes which were repeated often. Also caching of the FM sub-carrier location table would speed up the TDOA information lookup from the online database.

FM Sub-carrier Modulator

The reverse RF link back to the mobile device will be broadcast on a FM sub-carrier, which will utilize the unused spectrum in a FM radio station broadcast signal. This spectrum is located between 53 and 100 kHz above the main carrier frequency which is not used in the transmitting of the stereo music signal and can be used for broadcasting auxiliary programs and data. FM stations have the authority under their license to broadcast auxiliary programs and data without further permission from the Federal Communications Commission in the United States.

The maximum usable FM sub-carrier spectrum provides 47 kHz of available bandwidth. The FM sub-carrier modulator will broadcast 53Khz above the pre-programmed FM station licensed frequency with a maximum usable bandwidth of 47 kHz. The FM sub-carrier will be modulated to 10% of the total transmit power of the licensed Station. The FM sub-carrier modulator will utilize a highly efficient modulation scheme such as VMSK (Very-Minimum-Shift-Keying) or equivalent to produce the highest known modulation bandwidth efficiency for wireless communications. These modulation schemes achieve extremely high efficiencies in excess of 50 b/s HZ. This is achieved at RF by using biphase encoding (i.e. with a zero

transition in the middle of the symbol) in conjunction with the technique of single-sideband (SSB) suppressed carrier transmission. This yields a narrow spectrum devoid of Bessel products as well. By dividing the encoded data waveform by two, the bandwidth efficiency of the original VMSK method can be doubled, improving the signal-to-noise ratio by two to one. One characteristic of bi-phase encoding is that it produces an upper and lower sideband that is not located directly adjacent to the carrier as in a modulated (NRZ) non-return to zero type encoding. Bi-phase encoding moves the spectrum away form the zero carrier center, out to a position equal to the bit rate above and below the carrier. This allows the filtering of one of the sidebands to be done very easily and does not require sharp filters as in vestigial sideband transmission. The overall method of using VMSK with a carrier consists of generating a double sideband signal, filtering out the carrier and one sideband, then transmitting the desired sideband.

VMSK modulation does not actually encode logic 0 and 1 but polarity changes. A higher clock rate per bit is also employed. If the processed bit is the same polarity as the previous bit it is encoded as a polarity change on the encoded bit stream at the end of the bit. Otherwise, if it is of opposite polarity, it is encoded as a polarity change on the encoded bit stream at one clock period after the end of the bit. Actually, as the duration of the symbol is extended, the required bandwidth is reduced. This action cannot be extended infinitely. For this reason, after some bits, one bit will be missed. This bit is encoded with the use of an algorithm in order to be restored at the FM sub-carrier receiver. The local oscillator that is employed in the mixer stage will be a sub-multiple (divisible) by the stereo pilot frequency of 19 kHz and will be phase locked to the 19Khz pilot of the associated FM station that it is transmitting from. This is done so coherent detection can be done in the FM sub-carrier receiver.

The FM-modulator will have an Ethernet 10 base T electrical interface with an assigned programmable internal static IP address. This internal IP address will be unique for each FM station that will be connected to the Internet via an ISP and gateway IP address. The connection can be made by using any type of communication service supporting a data rate of a least a T1 (1.544 Mbps). Examples of such connections would be an E10, ADSL, Cable Modem, or Inverse Multiplexed ISDN. This will match the data rate of the FM sub-carrier modulator to allow for maximum data transmission and TCP/IP sessions per FM station.

CDPD/FM Receiver

The mobile device 1 will contain a CDPD transceiver as well as a secondary alternate receiver in the FM broadcast band. The Interface will be a PCMCIA ***Type*** III card or equivalent type interface. The CDPD PCMCIA card will be programmed to have an NEI (public IP address) and IP address of the WAP Gateway. The secondary receiver will also retain the same IP address as the CDPD Modem. The CDPD receiver uses the primary channel 8 and the FM receiver uses the secondary channel 9. The initial IP packet transmission from the mobile device's browser will communicate via the CDPD primary link 8. The IP packets will be transmitted over the reverse CDPD air-link towards the BTS. The NSAP 3 will forward the information through the Internet to the WAP Gateway. The gateway will return a confirmation packet back to the CPDP primary receiver via the forward air-link 8. With this being done the TDOA information has arrived to the WAP Gateway and now knows the location information of the mobile user as well as the IP address. The database 7 is now interrogated and the participating FM station closest to the mobile device is identified. Another two packets are sent back to the CDPD receiver via the forward portion of the primary

link 8. The first packet will contain an encryption key which will be forwarded to the mobile device's browser, and the second packet will provide the tuning or frequency information for the secondary receiver. The data decoder logic at the output of the CDPD receiver will forward the binary word to the D/A converter circuit which will feed the corresponding DC voltage to a voltage controlled oscillator to tune the secondary receiver to the specified frequency. Once tuned to the FM sub-carrier frequency a pilot detector verifies that it is locked onto the FM station. This is the pilot all stereo broadcasters send to control the sum and difference combining of the L+R and L-R channels. The 19 kHz pilot is usually modulated at 10% of the FM transmitters full rated power i.e. 10 Kwatts for 100 Kwatt transmitter. This 19 kHz pilot detector indicator signal will be used to generate a CSP. The CSP will be sent via the CDPD primary link 8 to inform the WAP Gateway if it has tuned to the specified reverse secondary link frequency. The WAP Gateway will update it's channel assignment table and use this information to route the intended information back to the mobile either via the primary CDPD link 8 or the FM sub-carrier secondary link by their corresponding IP Gateway addresses.

Also sent back over the reverse portion of the CDPD primary link 8 will be a status packet (CSP) containing the BER of the data being received off the secondary FM receiver.

The WAP Gateway then performs all NATs and routes all destined packets back to the mobile by reference to the IP routing information. Prior to sending any packets back to the mobile, the WAP Gateway will always check the channel assignment table for the latest CSP information to ensure it is routing to the correct receiver. The CSP signal of the reverse channel is sent periodically (only upon degraded FM signals) back on the reverse portion of the CDPD primary link 8 to keep the channel assignment table

current. Loss of pilot or degraded BER at the mobile will result in a change in the updated channel assignment table to instruct the WAP Gateway to communicate with the CDPD primary receiver. With the WAP Gateway performing these tasks only one receiver will be routed packets at any given instance. The secondary FM receiver will be tuned to a specific frequency by tuning fsynth as per a voltage controlled oscillator. A packet containing a binary value will be sent to the CDPD receiver over the cellular network from the host Setup server after a match of location and FM frequency is determined to tune the receiver. This packet will be diverted to the local oscillator in the FM receiver to tune it to the frequency that has been selected by the WAP Gateway.

The FM receiver will also tune and receive the stereo pilot signal at 19 kHz above the licensed frequency. This signal contains about 10% of the FM stations signal. This signal can be used as both a signal lock and quality indicator status (CSP) to be sent back to the WAP Gateway over the forward CDPD link. Loss of the pilot can also switch the receiver back to the CDPD receiver at any time. The host Setup server will know and control where the outgoing packets are to be sent by the status information being received from the mobiles reverse CDPD link on a regular interval.

The following is a description of the SC WAP protocol table for channel Set-up, Verification and Initial Response as illustrated in Fig. 2.

1 to 2 Mobile makes IP request to WAP Gateway (sends IP address, Gateway IP address and requested URL)
TDOA sends mobile's initial location information to WAP Gateway

3 to 4	WAP Gateway finds FM station in database according to TDOA; WAP Gateway sends FM sub-carrier tuning information and encryption packet to mobile; FM receiver tunes to FM sub-carrier frequency
5 to 6	Mobile sends channel status packet to WAP Gateway to update channel assignment table; TDOA sends mobile's location information to WAP Gateway
7 to 8	WAP does NAT translation to ping mobile on FM sub-carrier channel (for channel verification).
9 to 10	Mobile sends its IP address in response to ping over CDPD reverse channel (confirms FM channel assignment); TDOA sends mobile's updated location information to WAP Gateway to update channel assignment table
11 to 12	WAP Gateway performs NAT on mobile's original IP request address to route mobile's request information to the originally requested URL destination
13 to 14	Destination information returned to NAT'd WAP Gateway address
15 to 16	WAP Gateway performs NAT to route destination information to the IP address of the FM sub-carrier station and hence to the mobile
17 to 18	Mobile acknowledges receipt of destination information via CDPD reverse link

TDOA sends updated location information to WAP Gateway

The following is a description of the SC WAP protocol table for ongoing data transfer (the information exchange component of the communication session) as illustrated in Fig. 3

1 to 2	Mobile makes IP request to WAP Gateway (sends IP address, Gateway IP address and URL request)
	TDOA sends updated location information to WAP Gateway
3 to 4	WAP Gateway performs NAT on Mobile's original IP request address to route mobile's request information to the originally stipulated destination and to route the return information back to the WAP Gateway
5 to 6	Requested URL information returned to NAT'd WAP Gateway address
7 to 8	WAP Gateway performs NAT to route URL destination information to the IP address of the FM sub-carrier station and hence to the mobile
9 to 10	Mobile acknowledges receipt of destination information via CDPD reverse link
	TDOA sends updated location information to WAP Gateway
11 to 12	This line indicates the passage of time which is the repetition period for the online mobile user verification ping

13 to 14 WAP does NAT translation to ping mobile on FM sub-carrier channel for mobile user online verification. (This happens periodically throughout session see 11 to 12)

15 to 16 Mobile sends its IP address in response to ping via the CDPD reverse link (confirms mobile is still connected to WAP Gateway)

17 to 18 User session timeout limit is reached at the WAP Gateway: CSP information is cleared in the channel allocation table

19 to 20 WAP Gateway sends tuning information over CDPD to tune mobile's sub-carrier receiver to an out of band channel to await new assignment

It will be appreciated that although the preferred embodiment of the invention has been described in detail, variations and modifications thereto may be practised without departing from the scope of the invention.

CLAIMS

We claim:

1. A communication system comprising:

a plurality of two way mobile communication devices, said devices being capable of transmitting and receiving information in CDPD mode and having an FM radio broadcast receiver;

a CDPD network for transmitting and receiving information to and from said device in CDPD mode; and,

a broadcast facility associated with said communication system for FM radio broadcast transmission to at least one of said devices.

2. A communication system as in claim 1 wherein said radio transmission is by FM broadcast sub-carrier.

3. A method of using the communication system of claim 1 whereby one of said devices transmits in CDPD mode a request to access information residing in a wide area communication network, and the requested information is delivered to said device by FM broadcast radio transmission from said broadcast facility.

4. A method as in claim 3 wherein said requested information is substantially broader in bandwidth than said request.

5. A communication system as in claim 1 wherein a communication session involving one of said devices includes a channel set up segment for

establishing a radio transmission path to said device, and an information exchange segment.

6. A communication system as in claim 5 in which said channel set-up segment is conducted in CDPD mode.

7. A communication system as in claim 6 wherein said information exchange and retrieval segment includes the broadcast of information from said broadcast facility to said device on an FM broadcast sub-carrier channel.

8. A communication system as in claim 5, said communication system further comprising a server for coordinating communication paths in said system, and wherein said set-up segment comprises:

a first data packet dispatched from said device and addressed to said server, said first data packet including the IP address of said device; and,

a reply data packet from said server, said reply data packet being delivered to said wide area communication network and being routed to said CDPD network and to said device, said reply data packets identifying a radio frequency at which said device is to receive information during said information exchange segment.

9. A communication system as in claim 6 or 7, said communication system further comprising a server for coordinating communication paths in said system, and wherein said set-up segment comprises:

a first data packet dispatched from said device and addressed to said server, said first data packet including the IP address of said device; and,

a reply data packet from said server, said reply data packet being delivered to said wide area communication network and being routed to said CDPD network and to said device, said reply data packets identifying a radio frequency at which said device is to receive information during said information exchange segment.

10. A communication system as in claim 5 wherein said channel set-up segment comprises:

said device transmitting in CDPD mode;

determining the location of said device by comparing the receipt of said CDPD mode transmission at a plurality of said cellular base stations.

11. A communication system as in claim 10 wherein said broadcast facility is selected according to said location.

12. A communication system as in claim 10 wherein said location is determined using a time difference of arrival assessment and hyperbolic trilateration.

13. A communication system as in claim 11 wherein said broadcast facility is selected according to proximity to said location and signal quality associated with said location.

14. A communication system as in claim 8 wherein said set up segment occurs periodically throughout a communication session

15. A communication system as in claim 5 further comprising a server having an IP address, and wherein said communication session comprises:

outgoing data packets being transmitted from said device to a CDPD network in CDPD mode, said packets being addressed to said server and including a URL in a wide area communication network to which said device desires access;

said CDPD network routing said data packets to said wide area communication network, along with information identifying the location of said device, for delivery to said server;

said server formulating a reply message to be delivered in CDPD mode by said CDPD network to said device, said message identifying an FM radio frequency on which said device may receive information provided at said URL

16. A method for establishing a communication facility for a mobile communication device in a communication system according to claim 1 comprising dispatching a set up request in CDPD mode, receiving in CDPD mode information identifying an FM radio frequency for receipt of subsequent information, tuning said device to said FM radio frequency and subsequently receiving information during said communication session.

17. A method as in claim 16 wherein said set up request comprises the IP address of said device and the IP address of a server coordinating the establishment of communication paths in said communication system.

18. Use of the communication system of claim 1, 2, 3, 4, 5, 6, 7, 8 or 61.

19. A server for coordinating communication between a mobile communication device and an IP address on a wide area communication network, said communication involving at least two modes of communication, a first of said modes comprising transmission by a broadcast facility of information to said device by FM radio, and a second of said modes being different from said first mode.

20. A server as in claim 19 wherein said server has access to a database of broadcast facilities available for transmitting information at said server's request.

21. A server as in claim 20 wherein said server selects a broadcast facility from said database for said transmission.

22. A server as in claim 21 wherein said selection of a broadcast facility is based on the location of said device.

23. A server as in claim 22 wherein said server dispatches information to said device identifying an FM radio frequency at which said device may receive information during a communication session.

24. A server as in claim 20 wherein said server has an IP address on a wide area communication network.

25. A server as in claim 23 wherein said frequency is an FM sub-carrier frequency.

26. A server as in claim 23 wherein said broadcast facility is determined by correlating information regarding the location of said device to said database of broadcast facilities.

27. A server as in claim 26 wherein said server transmits encryption key information for facilitating decryption of an FM sub-carrier signal broadcast to said device.

28. A server as in claim 25 wherein said server confirms that said device is tuned to a designated FM sub-carrier frequency.

29. A server as in claim 28 wherein said server receives a data status packet originating from said device, receipt of said data status packet confirming that said device has tuned to a FM stereo pilot signal.

30. A server as in claim 29 wherein said server verifies that said device is tuned to the correct FM sub carrier frequency.

31. A server as in claim 30 wherein said server verifies that said device is tuned to said correct FM sub carrier frequency by dispatching a test packet to a wide area communication network, said test packet being addressed for broadcast from said broadcast facility to said device, and wherein said server detects a return packet from said device comprising said test packet.

32. A server as in claim 19 wherein said server interprets URL access requests from said device, retrieves the requested information from a wide area communication network, and delivers said information to a broadcast facility for broadcast to said device by FM radio transmission.

33. A server as in claim 32 wherein said server receives from said device said URL access requests in association with the IP address of said server, said server removes said server's IP address from said URL access request.

34. A server as in claim 23 wherein said server identifies from said database the IP address for a broadcast facility designated to deliver information in response to a URL access request from said device and said server dispatches information retrieved from said URL to said broadcast facility for tranmission by FM radio to said device.

35. A server as in claim 25 wherein said server ensures ongoing connectivity and quality of service by monitoring the quality of the FM radio signal received by said device.

36. A server as in claim 35 wherein said server receives from said device information regarding bit error rates in relation to said FM radio transmission to said device.

37. A server as in claim 36 wherein said bit error rates are received at said server via a CDPD link.

38. A server as in claim 19 wherein said server stores information regarding the quality of radio signal received by said device and dynamically correlates it with the location from time to time of said device to produce a quality of signal service database.

39. A server as in claim 37 wherein said server tracks movement of said device and correlates said movement to said signal service database to anticipate loss of acceptable signal quality.

40. A server as in claim 38 wherein said server allocates broadcast facilities for transmission to said device based on said anticipated loss of signal quality.

41. A server as in claim 38 wherein said information regarding quality of radio signal comprises bit error rates.

42. A server as in claim 19 wherein said server monitors communication session involving said device and said broadcast facility to detect inactivity or loss of connection.

43. A server as in claim 52 wherein said server maintains a channel assignment table identifying FM radio frequencies being used for communication, and wherein said server monitors said communication sessions and clears said channel assignment allocation for a communication session when the period of inactivity for said session exceeds a predetermined limit.

44. A server as in claim 19 wherein said server allocates levels of priority of service to individual communication session involving said devices.

45. A server as in claim 54 wherein said server employs load control software to allocate said levels of priority of service and one of said levels comprises Demand Access Multiple Assignment (DAMA) in which FM sub-carrier channels are assigned according to their availability and in which DAMA only sessions contend for use of said DAMA channels.

46. A server as in claim 55 wherein another of said levels comprises Partial Demand Access Multiple Assignment (PDAMA) in which a pool of

FM sub-carrier channels are dedicated to a pool of sessions and allocated only to members of a pre-assigned group.

47. A server as in claim 56 wherein another of said levels comprises Pre-Assigned Multiple Access (PAMA) is which a single channel is dedicated to a multiplicity of individual sessions such that the number of sessions does not exceed the on the capacity of said single channel.

48. A server as in claim 19 wherein said server tracks and prevents channel toggling caused by repeated bit error rate and pilot signal notifications received from said devices.

49. A communication device capable of transmitting in TCP/IP mode over a CDPD network, and of receiving TCP/IP information via an FM radio receiver tuned to an FM sub-carrier channel.

50. A communication device as in claim 49 wherein said communication device is mobile.

51. A communication device as in claim 50 wherein said device communicates with a host server for the purpose of determining a radio frequency to which said device should tune to receive said FM sub-carrier transmission.

52. A communication device as in claim 51 wherein said device functions in a full duplex CDPD mode during service request and FM channel assignment and in simplex FM sub-carrier mode (receive only) for data delivery.

53. A communication device as in claim 52 wherein said device transmits FM sub-carrier channel status information in CDPD mode.

54. A communication device as in claim 50 wherein said device contains bit error monitoring circuitry for detecting bit error rates when receiving FM radio transmissions.

55. A communication device as in claim 54 wherein said device monitors incoming FM data packets for acceptable bit error rates.

56. A communication device as in claim 54 further comprising signal monitoring and verification circuitry.

57. A communication device as in claim 49 containing circuitry for detecting and monitoring the presence of an FM stereo pilot signal, for verifying FM channel allocation and for dispatching to a communication server confirmation that the device has received said FM stereo pilot signal.

58. A communication device as in claim 49 wherein said device prevents channel toggling between the CDPD mode and the FM sub carrier mode caused by repeated unacceptable bit error rates and pilot signal fluctuations which would cause said device to become caught in a cycle of channel assignment and reassignment, by using hysteresis to define trigger parameters and creating a dead band in both the bit error rate and pilot level trigger points such that information regarding channel signal loss is not dispatched to a communication server monitoring said information.

59. Use of a communication system as in claim 1 to receive or transmit broadband information in TCP/IP mode.

60. A communication system as in claim 11 wherein said location is determined by correlating time difference of arrival information from a plurality of cellular base stations receiving a CDPD signal from said device and the GPS coordinates of said cellular base stations.

61. A communication system comprising:

a plurality of two way communication devices, said devices being capable of transmitting information in a first communications mode and of receiving information in a second communications mode; and

a transmission facility broadcasting to at least one of said two way communication devices in said second communications mode.

62. A communication system as in claim 61 wherein said device is a mobile device, said first communications mode is CDPD and said second communications mode is FM radio sub carrier.

63. A method of using the communication system of claim 61 whereby one of said devices transmits in said first communication mode a request to access information residing in a wide area communication network, and the requested information is delivered to said device by said transmission facility in said second communication mode.

64. A method as in claim 63 wherein said requested information is substantially broader in bandwidth than said request.

65. A communication system as in claim 61, 62, 63 or 64 further comprising a server for receiving and forwarding information requests originating with said communication devices and communicated to said

server via a wide area communication network, and for controlling the delivery of information responsive to said requests to at least one of said devices via said transmission facility.

66. A communication system as in claim 1 wherein loss or degradation of said FM broadcast radio transmission results in use of said CDPD network for transmission of information to said devices.

67. A communication system as in claim 1 wherein loss or degradation of signal transmitted in CDPD mode from said devices results in a reassignment of a CDPD channel for said transmission and said reassignment is independent of the assignment of a channel for said FM broadcast radio transmission.

68. A communication system as in claim 1 or 67 wherein loss or degradation of said FM broadcast radio transmission results in a reassignment of an FM channel and said reassignment is independent of the assignment of a channel for transmission from said devices.

69. A communication system as in claim 61 wherein loss or degradation of a channel in said second communication mode results in use of said first communication mode for transmission of information to said devices.

70. A communication system as in claim 61 wherein loss or degradation of signal transmitted in said first communications mode from said devices results in a reassignment of a channel in said first communications mode for said transmission and said reassignment is independent of the assignment of a channel for said second communication mode.

71. A communication system as in claim 61 or 70 wherein loss or degradation of signal in said second communication mode results in a reassignment of a channel in said second communication mode and said reassignment is independent of the assignment of a channel for transmission in said first communication mode.

72. A server as in claim 48 wherein toggling is prevented by establishing a minimum time parameter between bit error rate and pilot signal notifications such that no switching takes place unless minimum time parameters are exceeded.

73. A server as in claim 38 wherein said quality of signal service database includes information identifying at least one sub-carrier frequency in respect of which said quality of signal service data was compiled.

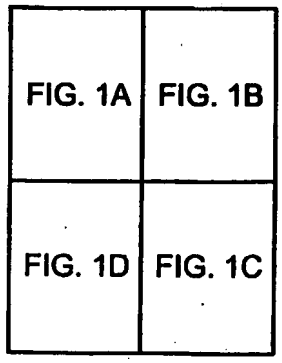
FIG. 1A
FIG. 1B
FIG. 1D
FIG. 1C

FIG. 1

(20)
FIXED TERMINAL DEVICE
MOBILE TERMINAL
(1)
COMPUTER TERMINAL
CDPD MODEM
BROWSER
FM SUB-CARRIER DEMODULATOR
PRIMARY CHANNEL
AIRLINK FORWARD & REVERSE CHANNELS
(8)
FM SUBCARRIER BROADCAST TO MOBILE WITH IP ADDRESS
(9)
CITY
(17)
FM SUB-CARRIER MODULATOR

FIG. 1A

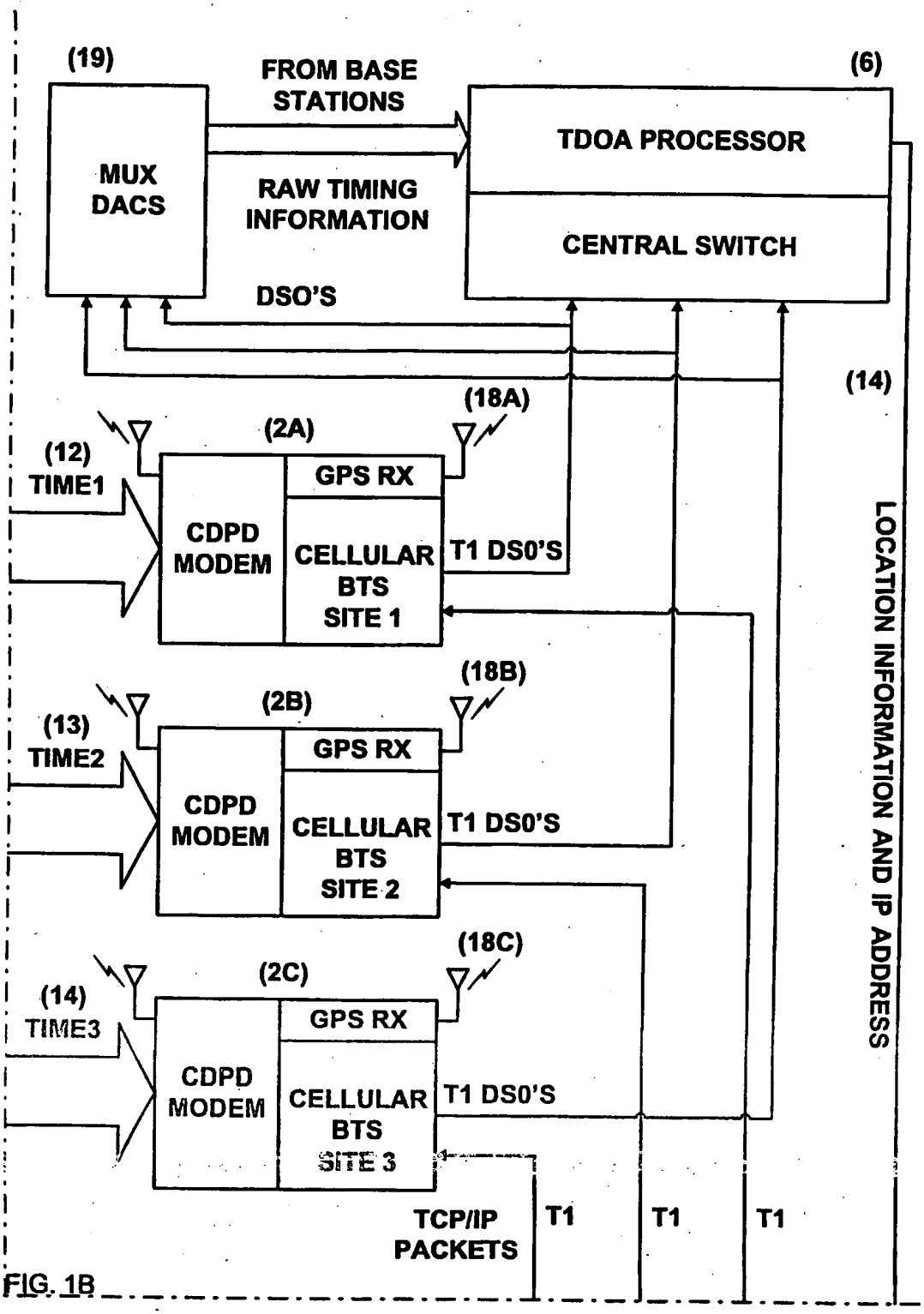
(19)
FROM BASE STATIONS
(6)
MUX DACS
TDOA PROCESSOR
RAW TIMING INFORMATION
CENTRAL SWITCH
DSO'S
(14)
(18A)
(2A)
(12) TIME1
GPS RX
CDPD MODEM
CELLULAR BTS SITE 1
T1 DS0'S
LOCATION INFORMATION AND IP ADDRESS
(18B)
(2B)
(13) TIME2
GPS RX
CDPD MODEM
CELLULAR BTS SITE 2
T1 DS0'S
(18C)
(2C)
(14) TIME3
GPS RX
CDPD MODEM
CELLULAR BTS SITE 3
T1 DS0'S
TCP/IP PACKETS
T1
T1
T1

FIG. 1B

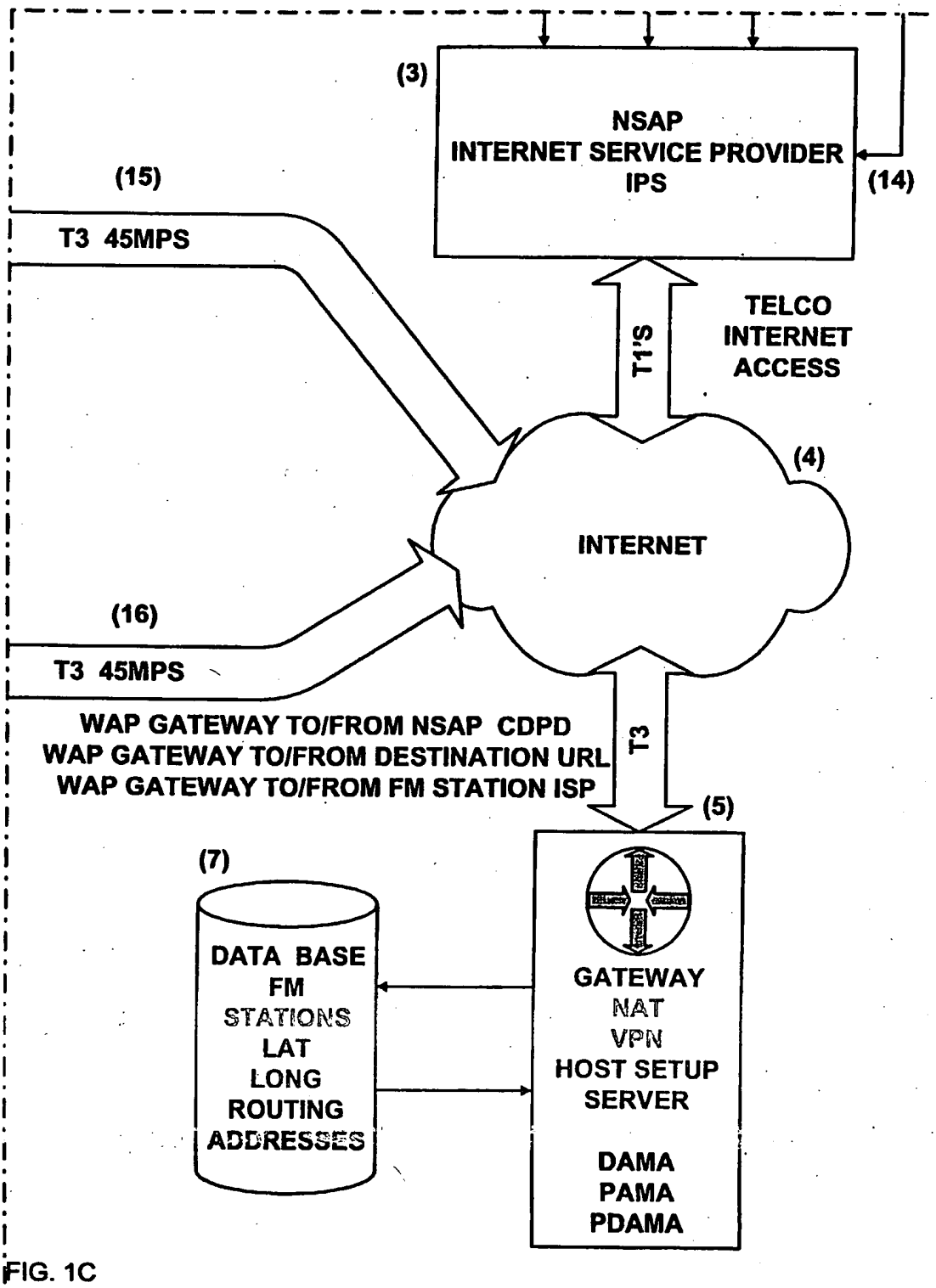
(3)
NSAP
INTERNET SERVICE PROVIDER
IPS
(14)
(15)
T3 45MPS
T1'S
TELCO
INTERNET
ACCESS
(4)
INTERNET
(16)
T3 45MPS
WAP GATEWAY TO/FROM NSAP CDPD
WAP GATEWAY TO/FROM DESTINATION URL
WAP GATEWAY TO/FROM FM STATION ISP
T3
(5)
(7)
DATA BASE
FM
STATIONS
LAT
LONG
ROUTING
ADDRESSES
GATEWAY
NAT
VPN
HOST SETUP
SERVER
DAMA
PAMA
PDAMA

FIG. 1C

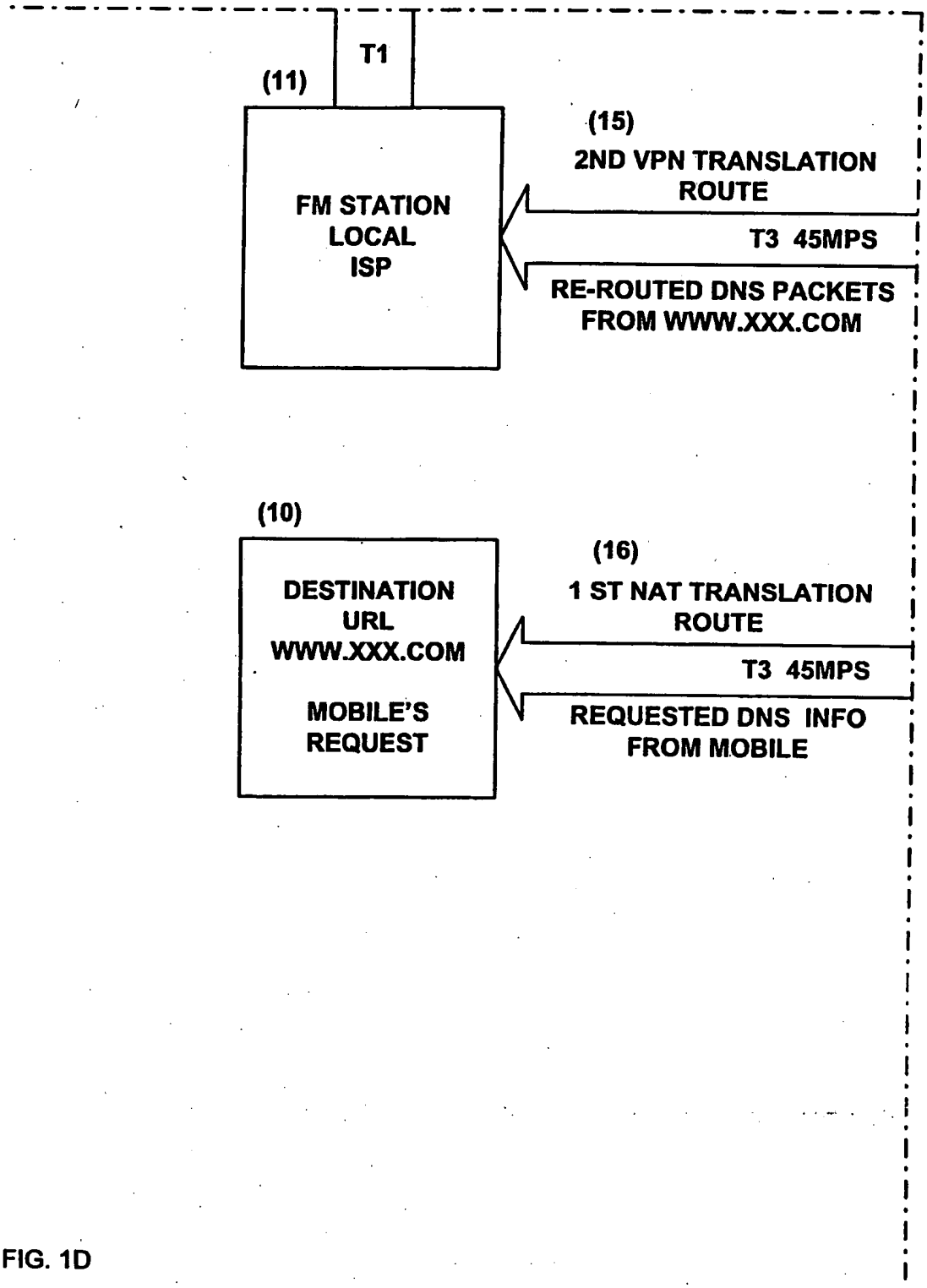
T1
(11)
FM STATION
LOCAL
ISP
(15)
2ND VPN TRANSLATION
ROUTE
T3 45MPS
RE-ROUTED DNS PACKETS
FROM WWW.XXX.COM
(10)
DESTINATION
URL
WWW.XXX.COM
MOBILE'S
REQUEST
(16)
1 ST NAT TRANSLATION
ROUTE
T3 45MPS
REQUESTED DNS INFO
FROM MOBILE

FIG. 1D

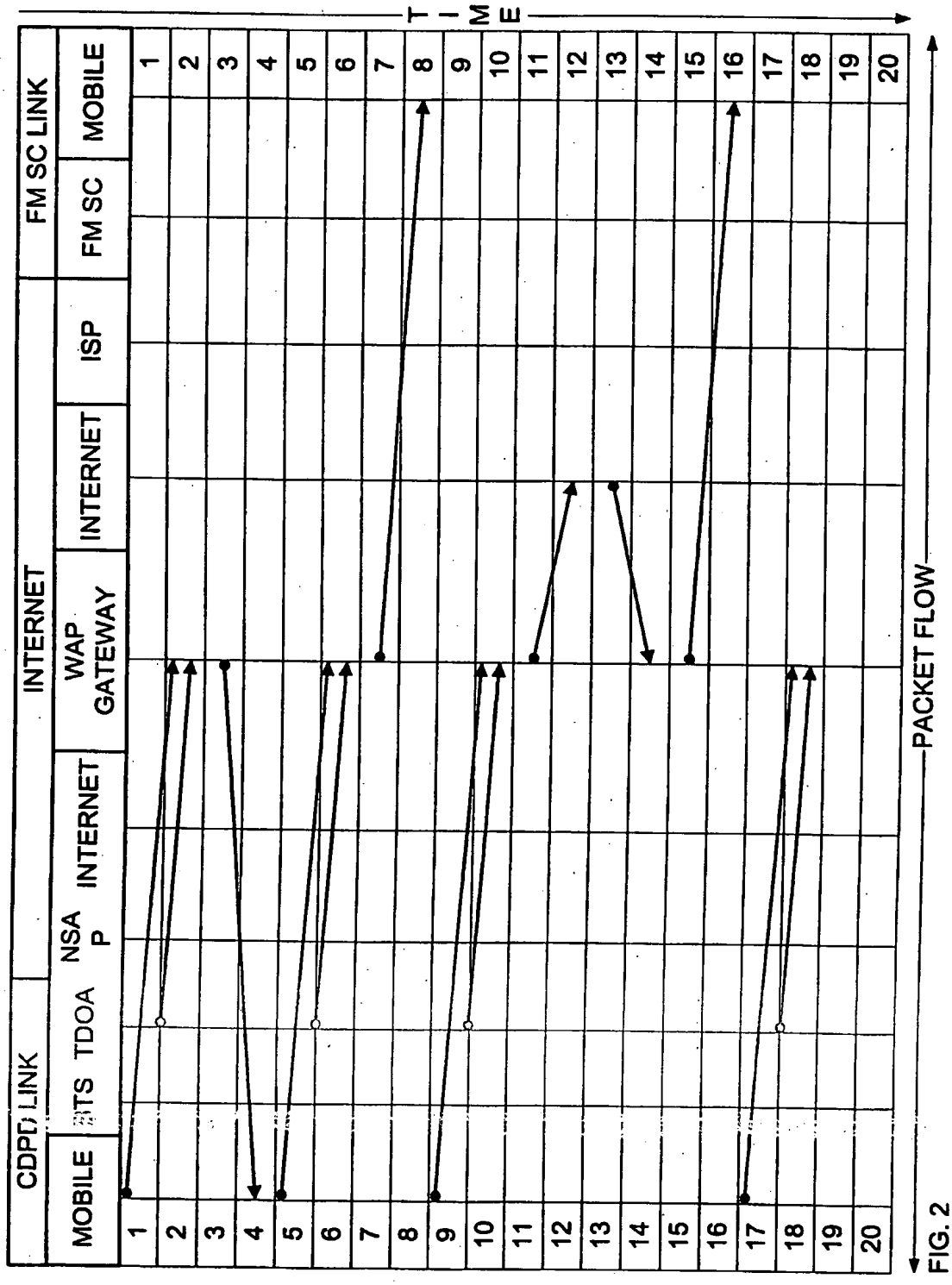
CDPD LINK
INTERNET
FM SC LINK
MOBILE
BTS
TDOA
NSA P
INTERNET
WAP GATEWAY
INTERNET
ISP
FM SC
MOBILE
TIME
PACKET FLOW
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FIG. 2

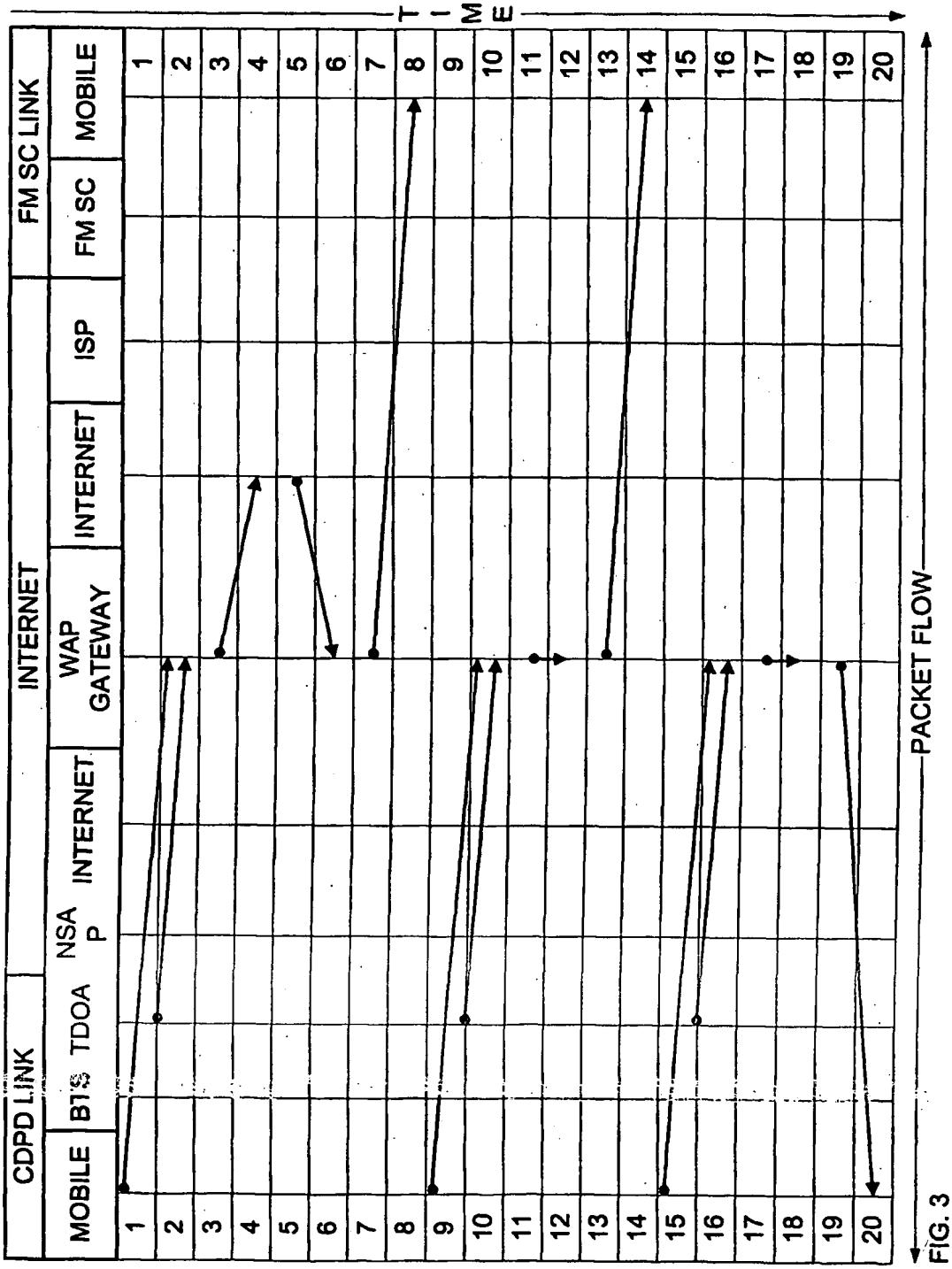
CDPD LINK
INTERNET
FM SC LINK
MOBILE
BTS
TDOA
NSA P
INTERNET
WAP GATEWAY
INTERNET
ISP
FM SC
MOBILE
TIME
PACKET FLOW
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FIG. 3